GP-300996

METHOD AND APPARATUS FOR OBTAINING A CONSISTENT PEDAL POSITION FOR A VEHICLE HAVING AN ENGINE WITH DISPLACMENT ON DEMAND

TECHNICAL FIELD

The present invention relates to the control of internal combustion engines. More specifically, the present invention relates to a method and apparatus to provide a consistent relationship between the position of an accelerator pedal and the output torque of a variable displacement internal combustion engine.

BACKGROUND OF THE INVENTION

Present regulatory conditions in the automotive market have led to an increasing demand to improve fuel economy and reduce emissions in present vehicles. These regulatory conditions must be balanced with the demands of a consumer for high performance and quick response in a vehicle. Variable displacement internal combustion engines (ICEs) provide for improved fuel economy and torque on demand by operating on the principal of cylinder deactivation. During operating conditions that require high output torque, every cylinder of a variable displacement ICE is supplied with fuel and air (also spark, in the case of a gasoline ICE) to provide torque for the ICE. During operating conditions at low speed, low load, and/or other inefficient conditions for a fully displaced ICE, cylinders may be deactivated to improve fuel economy for the variable displacement ICE and vehicle. For example, in the operation of a vehicle equipped with an eight-cylinder variable displacement ICE, fuel economy will be improved if the ICE is operated with only four cylinders during low torque operating conditions by reducing throttling losses. Throttling losses, also known as pumping losses, are the extra work that an ICE must perform to pull air around the restriction of a relatively closed throttle plate and pump air from

the relatively low pressure of an intake manifold through the ICE and out to the atmosphere. The cylinders that are deactivated will not allow air flow through their intake and exhaust valves, reducing pumping losses by forcing the ICE to operate at a higher intake manifold pressure. Since the deactivated cylinders do not allow air to flow, additional losses are avoided by operating the deactivated cylinders as "air springs" due to the compression and decompression of the air in each deactivated cylinder.

In past variable displacement ICEs, when partially displaced, the operator would have to alter the position of an accelerator pedal to produce the same torque as when the ICE is fully displaced. Previous variable displacement ICEs were equipped with conventional pedal-throttle-wire couplings that required different accelerator pedal positions for the operation of a fully-displaced ICE and a partially-displaced ICE. The physical coupling between the accelerator pedal and throttle, and the inability to control throttle position as a function of displacement in previous variable displacement ICEs, prevented compensation in the accelerator pedal position for changes in output torque. The amount of air flow through the throttle required to generate the same torque for a fully-displaced and partially-displaced operation was different, requiring the physical position of the throttle plate and accelerator pedal to be different in the various operating configurations for a variable displacement ICE. Accordingly, the amount of movement in the accelerator pedal required to change the amount of torque for a fully-displaced and partially-displaced engine was also different. These differences in accelerator pedal operation, to generate the same torque for different modes of operation for a previous variable displacement engine, were nuisances to the operator of the vehicle.

The introduction of new engine control devices such as electronic throttle control (ETC), engine controllers, position sensors for pedal controls, and other electronics has enabled tighter control over more functions of an

ICE. It is an object of the present invention to provide a variable displacement ICE whose operation is transparent to the operator of a vehicle.

SUMMARY OF THE INVENTION

The present invention is a method and apparatus that produces a consistent relationship between engine torque and accelerator pedal position for a vehicle equipped with a variable displacement internal combustion engine (ICE). In the preferred embodiment of the present invention, an eight-cylinder internal combustion engine (ICE) may be operated as a four-cylinder engine by deactivating four cylinders. The cylinder deactivation occurs as a function of load or torque demand by the vehicle. An engine or powertrain controller will determine if the ICE should enter four-cylinder mode by monitoring the load and torque demands of the ICE. If the ICE is in a condition where it is inefficient to operate with the full complement of eight cylinders, the controller will deactivate the mechanisms operating the valves for the selected cylinders and also shut off fuel (and possibly spark in the case of a gasoline engine) to the cylinders. The deactivated cylinders will thus function as air springs to reduce throttling and pumping losses.

As previously described, the transition between eight cylinders to four cylinders or four cylinders to eight cylinders will create changes in the air flow through the throttle plate into the ICE that also affect the torque output of the ICE and consequently the accelerator pedal position needed to generate a specific torque. The method and apparatus of the present invention uses electronic throttle control (ETC) to maintain the same engine torque and accelerator pedal position during and after a cylinder deactivation and reactivation process for the variable displacement ICE. The implementation and integration of the control schemes of the present invention will allow for a seamless transition from all cylinders firing (reactivation) to half the cylinders firing (deactivation) without disturbing the operation of the accelerator pedal.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagrammatic drawing of the control system of the present invention; and

Figure 2 is a process control diagram for the control system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 is a diagrammatic drawing of the vehicle control system 10 of the present invention. The control system 10 includes a variable displacement ICE 12 having fuel injectors 14 and spark plugs 16 controlled by an engine or powertrain controller 18. The ICE 12 crankshaft 21 speed and position are detected by a speed and position detector 20 that generates a signal such as a pulse train to the engine controller 18. The ICE 12 may comprise a gasoline ICE, or any other ICE known in the art. An intake manifold 22 provides air to the cylinders 24 of the ICE 10, the cylinders having valves 25. The valves 25 are further coupled to an actuation apparatus such as a camshaft 27 used in an overhead valve or overhead cam configuration that may be physically coupled and decoupled to the valves 25 to shut off air flow through the cylinders 24. An air flow sensor 26 and manifold air pressure (MAP) sensor 28 detect the air flow and air pressure within the intake manifold 22 and generate signals to the powertrain controller 18. The airflow sensor 26 is preferably a hot wire anemometer, and the MAP sensor 28 is preferably a strain gauge.

An electronic throttle 30 having a throttle plate controlled by an electronic throttle controller 32 controls the amount of air entering the intake manifold 22. The electronic throttle 30 may utilize any known electric motor or actuation technology in the art including, but not limited to, DC motors, AC motors, permanent magnet brushless motors, and reluctance motors. The electronic throttle controller 32 includes power circuitry to modulate the electronic throttle 30 and circuitry to receive position and speed

input from the electronic throttle 30. In the preferred embodiment of the present invention, an absolute rotary encoder is coupled to the electronic throttle 30 to provide speed and position information to the electronic throttle controller 32. In alternate embodiments of the present invention, a potentiometer may be used to provide speed and position information for the electronic throttle 30. The electronic throttle controller 32 further includes communication circuitry such as a serial link or automotive communication network interface to communicate with the powertrain controller 18 over an automotive communications network 33. In alternate embodiments of the present invention, the electronic throttle controller 32 may be fully integrated into the powertrain controller 18 to eliminate the need for a physically separate electronic throttle controller.

A brake pedal 36 in the vehicle is equipped with a brake pedal sensor 38 to determine the amount of pressure generated by an operator of the vehicle on the brake pedal 36. The brake pedal sensor 36 generates a signal to the powertrain controller 18 to determine a braking condition for the vehicle. A braking condition will indicate a low torque/low demand condition for the variable displacement ICE 12. An accelerator pedal 40 in the vehicle is equipped with a pedal position sensor 42 to sense the position of the accelerator pedal. The pedal position sensor 42 signal is also communicated to the powertrain controller 18. In the preferred embodiment of the present invention, the brake pedal sensor 38 is a strain gauge and the pedal position sensor 42 is an absolute rotary encoder.

Figure 2 is a process control diagram for the control system 10 of the present invention. The control system 10 of the present invention is based on controlling the electronic throttle 30 to provide a consistent position or feel for the accelerator pedal 40 to generate the same torque in the ICE 12 when it is partially displaced or fully displaced. The powertrain controller 18 and electronic throttle controller 32 of the present invention include software to execute the methods of the present invention.

Referring to Figure 2, at block 50 of the process diagram, a reference torque model based on the ICE 12 displacement is used to develop a torque map or lookup table which determines the amount of torque that the driver is requesting (T_{DES}) based on ICE 12 crankshaft 21 revolutions per mintue (RPMs) and accelerator pedal 40 position. The powertrain controller 18 determines the accelerator pedal 40 position from the signal generated by the pedal position sensor 42. The powertrain controller 18 further determines the rotations/minute (RPMs) of the ICE 12 crankshaft 21 from the pulse train generated from the crankshaft speed sensor 20.

At block 52, the powertrain controller 18 computes a desired mass air flow or the mass-air/cylinder (MAC) needed to produce the desired torque in the ICE 12 with only half (preferably four for an eight-cylinder ICE) and all of the of the cylinders 24 activated. The term activated for a cylinder 24 will be characterized as supplying a cylinder 24 with air, fuel, and spark or any permutation thereof. The desired air mass or MAC determined at block 52 is preferably determined by using the T_{DES} and the ICE 12 crankshaft RPM in conjunction with a lookup table stored in the powertrain controller 18 memory. At block 54, the powertrain controller 18 computes the nominal electronic throttle 30 position (or area) needed to produce the T_{DES} based in the ICE 12 with only half (preferably four for an eight-cylinder ICE) and all of the cylinders 24 activated. Generally, when running on half of the cylinders 24, it will require a larger throttle opening for the ICE 12 to generate a given torque. The nominal electronic throttle 30 position is preferably determined by using the T_{DES} and the crankshaft 21 RPM feedback in conjunction with a lookup table stored in the powertrain controller 18 memory.

At block 56, the powertrain controller 18 operates a MAC servo control scheme operating in closed loop mode to insure that the requested MAC is achieved. The MAC servo control corrects or trims the nominal throttle position based on the actual measured air mass determined by the

powertrain controller 18. The measured mass air flow comprises the process variable for the MAC servo method, the setpoint is the desired mass air flow, and the MAC servo method output is the throttle position correction. The MAC servo method may comprise a control algorithm based on fuzzy logic, proportional-integral-derivative methods, and/or neural networks. The measured mass air per cylinder may utilize the actual readings of the air flow sensor 26 or a processed/conditioned mass air flow reading based on the processing of the MAP sensor 28, the air flow sensor 26 and/or the throttle position sensor. Under nominal conditions, torque is proportional to the mass of air inducted into the ICE 12. Accordingly, the MAC servo method ultimately determines a throttle position correction necessary to achieve the T_{DES}. The throttle position correction component compensates for vehicle-vehicle differences, throttle wear, and other variations in the throttle flow characteristics.

A summer 58 adds the throttle position correction generated at block 56 to the nominal required throttle position generated at block 54. The final throttle position command is communicated from the powertrain controller 18 to the electronic throttle controller 32 to execute the final throttle position command for the ICE 12.

While this invention has been described in terms of some specific embodiments, it will be appreciated that other forms can readily be adapted by one skilled in the art. Accordingly, the scope of this invention is to be considered limited only by the following claims.